Kinematics
Part I: Motion in 1 Dimension

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Jan 7, 2020

Last time

- introduced the course

Overview

- basic ideas about physics
- units and symbols for scaling units
- dimensional analysis
- motion in 1-dimension
- kinematic quantities
- graphs

What is Physics?

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Physicists (and others who use physics) want to predict accurately how an object or collection of objects will behave when interacting.

Why?

- to better understand the universe
- to build new kinds of technology (engines, electronics, imaging devices, mass manufacturing, energy sources)
- to build safer and more efficient infrastructure
- to go new places and explore
- to prepare for the future

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(Philosophy) moral of the story: Physics is not about explaining how the world actually is. It is about finding models that make correct predictions.

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Theory

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Valid when

- $v << c$,
- gravitational fields are not too strong,
- distances are much bigger than ℓ_p (Planck length), etc.

What Other Physical Theories Do You Know Of?

?

Newtonian Mechanics

This course will only cover Newtonian Mechanics.

- We will look at motion from knowing the acceleration and object experiences.
- We will analyze **forces** to consider what acceleration an object will experience.
- We will also consider the **energy** of a system to find its motion.

There are other ways of doing this analysis: Lagrangian Mechanics and Hamiltonian Mechanics. They are not covered in the course.

Quantities, Units, Measurement

If we want to make *quantitative* statements we need to agree on measurements: standard reference units.

We will mostly use SI (Système International) units:

Length	meter, m
Mass	kilogram, kg
Time	second, s

These base units are defined in terms of **fundamental physical phenomena** - things anyone, anywhere could in principle observe consistently.

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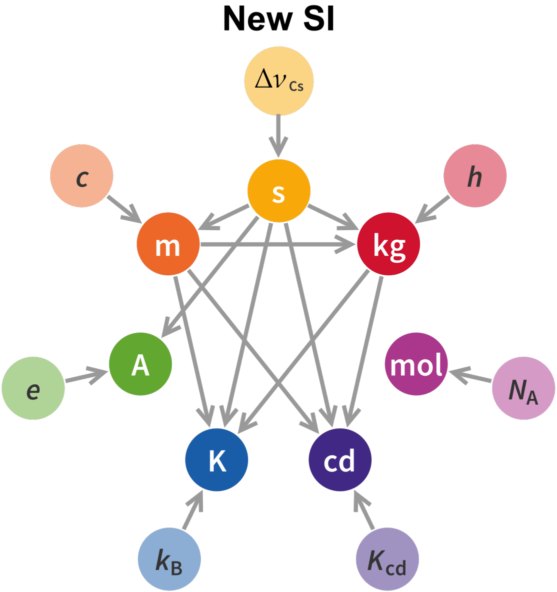
Make sure you include the appropriate units in your answer when you get a number!

Also, units can be helpful for checking that your equation is correct.

SI Units Definition Summary



[1]Figure by Emilio Pisanty.

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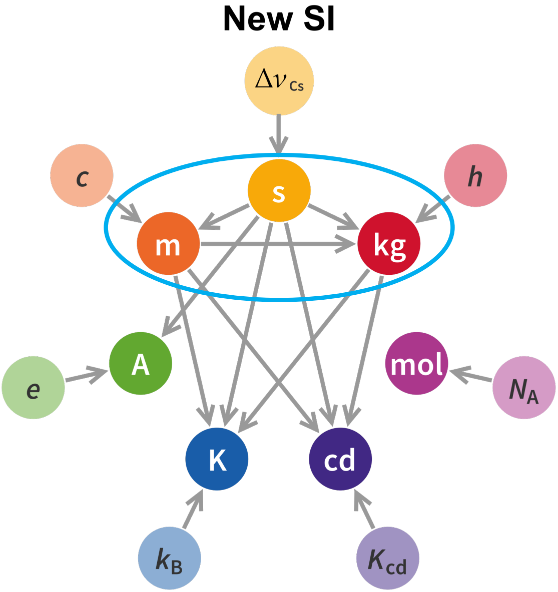

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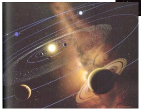
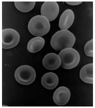
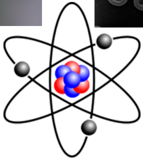
Scale of Units

Scale	Prefix	Symbol
10^{21}	zetta	Z
10^{15}	peta	P
10^{12}	tera-	T
10^{9}	giga-	G
10^{6}	mega-	M
10^{3}	kilo-	k
10^{2}	hecto-	h
10^{1}	deka-	da
10^{0}	—	—
10^{-1}	deci-	d
10^{-2}	centi-	c
10^{-3}	milli-	m
10^{-6}	micro-	μ
10^{-9}	nano-	n
10^{-12}	pico-	p
10^{-15}	femto-	f

Scale of Units

You need to know for this course:

Scale	Prefix	Symbol
10^3	kilo-	k
10^0	—	—
10^{-1}	deci-	d
10^{-2}	centi-	c
10^{-3}	milli-	m

Units are Useful: Dimensional Analysis

Considering the units or dimensions of each term on both sides of an equation can sometimes help spot faulty equations right away.

[1] Serway & Jewett, Page 16, # 9.

Units are Useful: Dimensional Analysis

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Which of the following equations are dimensionally correct?

(1) $v_f = v_i + ax$

(2) $y = (2\text{ m})\cos(kx)$, where $k = 2\text{ m}^{-1}$.

[1] Serway & Jewett, Page 16, # 9.

Units are Useful: Dimensional Analysis

(1) Units of $v_f = v_i + ax$:

$$[\text{ms}^{-1}] = [\text{ms}^{-1}] + [\text{ms}^{-2}] \times [\text{m}]$$

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(1) Units of $v_f = v_i + ax$:

$$
\begin{aligned}
[\mathrm{ms}^{-1}] &= [\mathrm{ms}^{-1}] + [\mathrm{ms}^{-2}] \times [\mathrm{m}] \\
[\mathrm{ms}^{-1}] &= [\mathrm{ms}^{-1}] + [\mathrm{m}^2\ \mathrm{s}^{-2}]
\end{aligned}
$$

No. (1) is not dimensionally correct.

Units are Useful: Dimensional Analysis

(2) Units of $y = (2\text{ m})\cos(kx)$

$$\begin{aligned}[\text{m}] &= [\text{m}] \times \cos([\text{m}^{-1}] \times [\text{m}]) \\ [\text{m}] &= [\text{m}]\end{aligned}$$

Yes. (2) is dimensionally correct.

Kinematics: Motion in 1 Dimension

First we consider particles constrained to move only along a straight line, forwards or backwards.

Vectors

scalar

A scalar quantity indicates an amount. It is represented by a real number. (Assuming it is a physical quantity.)

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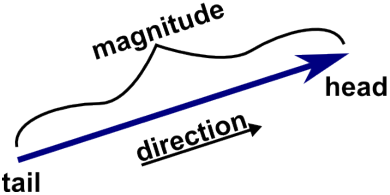
vector

A vector quantity indicates both an amount and a direction. It is represented by a real number for each possible direction, or a real number and (an) angle(s). (Assuming it is a physical quantity.)



Notation for Vectors

In the lecture notes vectors are represented using **bold** variables or **bold** variables with over-arrows.

Example:

k is a scalar

$\vec{\mathbf{x}}$ (or $\mathbf{x}$) is a vector

In the textbook and in writing, vectors are often represented with an over-arrow: $\vec{\mathbf{x}}$

The magnitude of a vector, $\vec{\mathbf{x}}$ is written:

$$|\vec{\mathbf{x}}| = x$$

Position

Some Quantities

position	$\vec{\mathbf{r}}$	(component: x)
displacement	$\overrightarrow{\boldsymbol{\Delta r}}$	(component: Δx)
distance	d	

Going between 2 points:

Distance is the length of a path that connects the two points.

Displacement is the length, together with the direction, of a straight line that connects the two points.

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Some Quantities

position	$\vec{\mathbf{r}}$	(component: x)
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Position and displacement are *vector* quantities.

Position and displacement can be positive or negative numbers.

Distance is a *scalar*. It is always a positive number.

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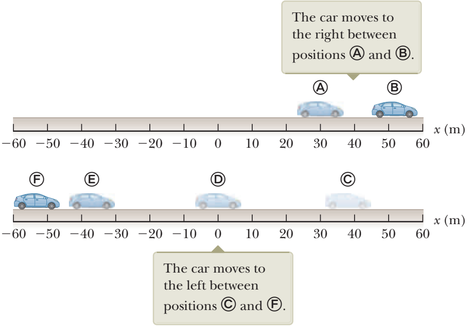
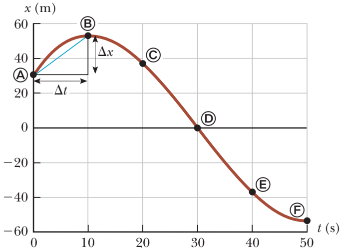
Units: meters, m

Position vs. Time Graphs





[1] Figures from Serway & Jewett

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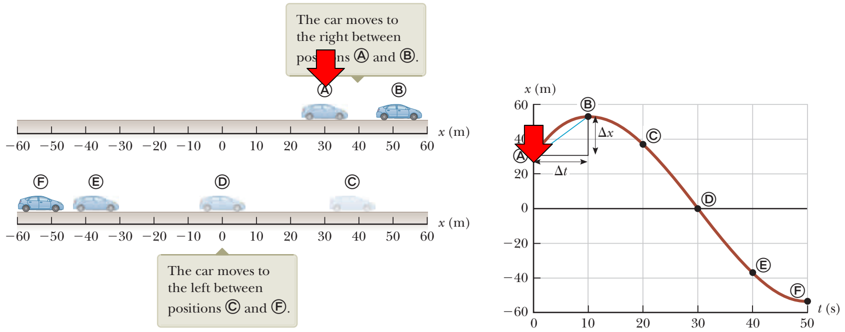

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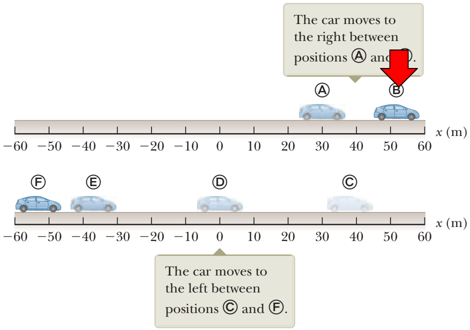

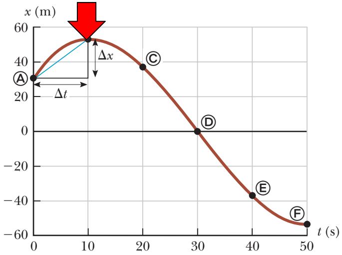

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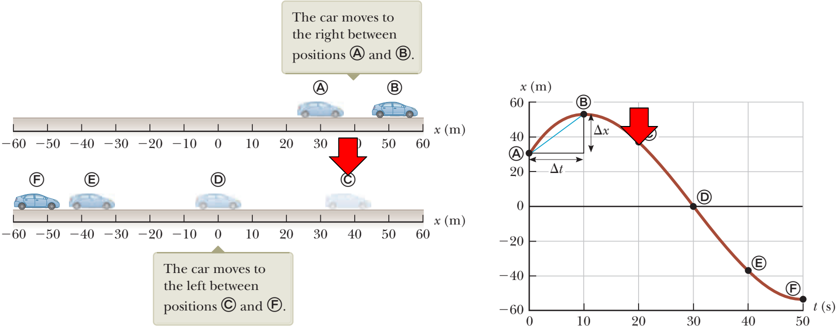

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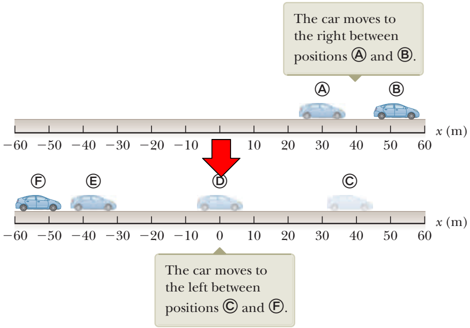

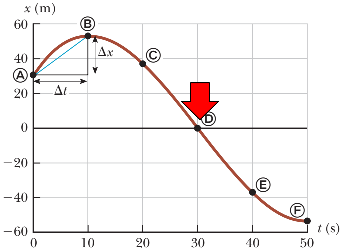

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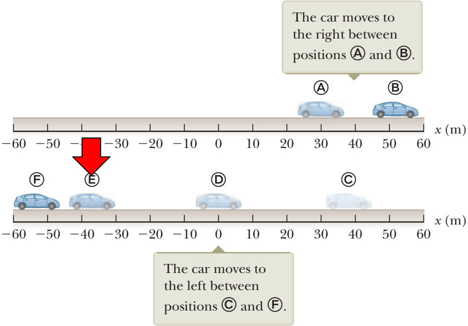

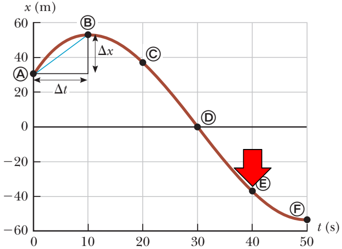

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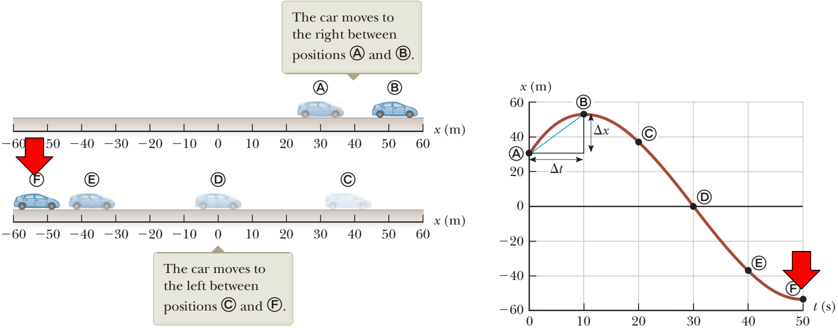

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Summary

- some quantities for describing motion: position $\vec{\mathbf{r}}$, velocity $\vec{\mathbf{v}}$, time t
- position, displacement, and velocity are vector quantities (have signs)
- distance and speed are scalar quantities (always positive)
- we can plot these quantities against time

Quiz Friday, start of class

(Uncollected) Homework

Serway & Jewett,

- Ch 1, onward from page 14. Problems: 9, 45, 57, 67, 71
- Ch 2, onward from page 49. Obj. Q: 1; CQ: Concep. Q: 1; Probs: 1, 3, 7, 11